FRESH AIR IN THE LIGHT OF RECENT RESEARCH

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EDITORIAL NOTE

Prof. Winslow's article might also be headed "Why Is Bad Air." For the first time in history, scientific experiment has actually produced evidence against bad, stagnant air, which must convict it of a crime against the human body before the bar of any unprejudiced opinion. Readers of the JOURNAL OF THE OUTDOOR LIFE *are fortunate in having the results of these most interesting experiments by the New York State Commission on Ventilation summarized by a man who is recognized as one of the greatest experts in this field. Dr. Holman's article on "Smoke, In Its Relation to Health" on another page of this issue, reporting on experiments conducted entirely independently from those of Prof. Winslow, gives interesting confirmation of the work done in New York City.*

THE EDITOR

Fresh Air and Health

The belief that the stagnant air of occupied rooms is prejudicial to human health and well being and that fresh outdoor air is a correspondingly beneficial agent in the cure and prevention of certain classes of disease, rests upon a sound basis of well established fact.

There can be no doubt, as a matter of common experience, that people in crowded and unventilated rooms suffer from certain definite symptoms of discomfort, of which lassitude and headache are among the common manifestations. Under very extreme conditions, as in the Black Hole of Calcutta, the hold of the ship Londonderry, or the underground prison at Austerlitz, the imprisonment of large numbers of persons in a confined space may result in death within a few hours.

On the other hand, medical experience teaches very clearly that patients suffering from certain respiratory diseases, notably from tuberculosis, are markedly benefited by life in the open air and that those who habitually live an outdoor life are far less susceptible to respiratory disorders and such infections as the common cold than are those who spend much of their time indoors in closed rooms. The conclusion of Benjamin Franklin "that people who life in the forest, in open barns or with open windows, do not catch cold, and that the disease called 'a cold' is generally caused by impure air, lack of exercise, or from overeating," has been only confirmed by time.

Any scientific study of the problems of ventilation must start with these conclusions as part of its fundamental premises.

Physiological Investigations in Regard to the Particular Properties which Make Air Good or Bad

Science cannot rest with the simple empirical conclusion that bad air is bad, but must attempt so far as possible to find out in what its badness specifically consists. In the solution of this important problem, Physiology has made considerable progress during the last twenty years.

The changes which take place in the air of a confined space as a result of human occupancy may be grouped for convenience under three main heads. In such spaces there is a decrease in oxygen and an increase in carbon dioxide, as a direct result of the respiratory process; there is an increase of certain organic compounds which produce characteristic stuffy odors, derived from the decomposing organic matter in the mouths and on the bodies and clothing of the occupants; and there is an increase of temperature and humidity due to the production of heat and moisture by the body.

The most natural assumption, and the one which is still perhaps dominant in the popular mind, is the assumption that a lack of oxygen and an excess of carbon dioxide is responsible for the harmful effects of vitiated air. This view, however, was long ago tested and proved to be erroneous. In 1863 the pioneer of German hygienists, von Pettenkofer, showed that the most extreme changes in oxygen and carbon dioxide content which ever occur under ordinary conditions in the worst ventilated room are far below the threshold at which harmful physiological effects can be produced. A reduction of oxygen from 21 per cent. to 19 per cent. and an increase of carbon dioxide from 4 parts per 10,000 to 40 parts, is the extreme range of variation which we find in the worst ventilated school or factory. The air in the lungs, however, under normal conditions, contains 16 per cent. of oxygen and 5 per cent. of carbon dioxide, and the respiratory apparatus easily accommodates itself to considerable changes in the composition of the atmosphere by slight automatic increases in

the rate of respiration so as to maintain the composition of the alveolar air unchanged. Not until the oxygen is reduced to 14 per cent. and the carbon dioxide increased to 300 parts per 10,000 can any harmful physiological effects be demonstrated.

When it was shown that the changes in oxygen and carbon dioxide content could not account for the effects of vitiated air, hygienists naturally turned their attention to the organic matter, the presence of which is so obvious to the sense of smell in a crowded and ill-ventilated room. It was suggested that some specific crowd poison, morbific matter, anthropotoxin, might be given off from the lungs or body, and a number of investigators, among whom perhaps the most influential was Brown-Sèquard, have claimed an actual demonstration of such poisons. Each time this has occurred, however, later researches with more carefully controlled methods have yielded negative results. The most recent case of this kind is the paper by Rosenau and Amoss (1911) in which these workers attempted to show the presence of specific proteid materials (but not necessarily of poisonous nature) in expired air by means of the very delicate reactions of anaphylaxis. This work has since been repeated by three independent investigators, by Leonard Hill in England, by Charles Weissman at the College of Physicians and Surgeons, New York, and by D. R. Lucas, working under the direction of Prof. Chas. Baskerville and myself, in each case with results which tend to negative those of Prof. Rosenau.

Meanwhile the researches of Flügge (1905) and many other investigators have shown that the third change in the atmospheric condition of an occupied room—its increase in temperature and humidity—unlike the chemical changes which have been discussed, does produce clearly and definitely demonstrable physiological effects. In these experiments it was shown that when subjects were placed in a closed chamber, the carbon dioxide and the odor and the temperature and humidity all increased while the subjects experienced feelings of serious discomfort and showed definite symptoms of physiological derangement. If the chamber were kept cool, however, without changing the air in any degree, these feelings were relieved, and Leonard Hill describes a group of such subjects laughing and chatting and trying to light cigarettes when the oxygen had fallen to 17 per cent. and the matches would not burn. Unfavorable symptoms could even be abolished within certain limits by merely stirring up the air in the chamber by means of an electric fan and thus breaking up the layer of excessively hot, moist air which clings to and surrounds the body. On the other hand, if these subjects were allowed to remain in the hot, moist room, but were given pure outside air to breathe through a tube, their feelings of discomfort were not relieved at all. Nothing could well be clearer or more definite. The ordinary symptoms experienced in a badly ventilated (and therefore overheated) room can be reproduced at will by exposing subjects to a warm atmosphere even if they breathe pure air. These symptoms of discomfort cannot be reproduced by breathing foul air if the temperature be kept low. As Prof. F. S. Lee has so well phrased it, the cause of these common and obvious results of bad ventilation has been shown to be physical and cutaneous, rather than chemical and pulmonary.

The Work of the New York State Commission on Ventilation

The New York State Commission on Ventilation was appointed by the Governor in 1913 at the request of the New York Association for Improving the Condition of the Poor and was given by the Association a fund of $50,000 for its work, this fund being a part of a large sum given by Mrs. Elizabeth Milbank Anderson for various phases of constructive social investigation. The members of the Commission are Mr. D. D. Kimball, Prof. Frederic S. Lee, Dr. James Alexander Miller, Prof. E. B. Phelps, Prof. E. L. Thorndike and the writer.

The Commission equipped two experimental rooms at the College of the City of New York (through the courtesy of the Trustees of the college), and in these rooms installed apparatus which makes it possible to control the temperature, humidity, chemical composition and rate of air change with a high degree of accuracy. In these rooms over 100 human subjects have been under observation for from four to eight hours a day over periods of from one to eight weeks, and their physiological and psychological condition, as well as their comfort and efficiency under varying atmospheric conditions, have been studied in detail.

The results of these experiments to date have tended in large measure to confirm and extend the investigations of Flügge and other earlier physiologists and hygienists. The following conclusions may be quoted from a Progress Report published by the Commission in the *American Journal of Public Health* for February, 1915, to indicate their general trend:

1. A very high room temperature such as 86 degrees F. with 80 per cent. relative humidity produces slight but distinct elevation of body temperature, an increase in reclining heart rate, an increase in the excess of standing over reclining heart rate, a very slight lowering of systolic blood pressure, and a marked fall in the Crampton value.

2. A moderately high room temperature, 75 degrees with 50 per cent. relative humidity, has all the effects noted above, although of course in less degree than the extreme temperature condition.

3. Even the extreme room temperature of 86 degrees with 80 per cent. relative humidity shows no effect upon respiration, dead space in the lungs, acidosis of the blood, respiratory quotient, rate of heat production, rate of digestion, protein metabolism, concentration of the urine and skin sensitivity.

4. The power to do either mental or physical work when actually working in a concentrated fashion is not at all diminished by a room temperature of 86 degrees with 80 per cent. relative humidity.

5. On the other hand the inclination to do physical work is certainly, and the inclination to do mental work is probably, diminished by high room temperatures. So far as physical work is concerned, our tests show a decrease in actual work performed, when the subject had a choice, of 15 per cent. under the 75 degrees condition and of 37 per cent. under the 86 condition as compared in each case with 68 degrees.

6. Stagnant air at the same temperature as fresh air, even when it contains 20 or more parts of carbon dioxide and all the organic and other substances in the breathed air of occupied rooms, has no effect on any of the physiological responses listed above under 1 and 3, nor on the power or inclination to do physical or mental work, nor on the sensations of comfort of the subjects breathing it.

In other words, an overheated—even a moderately overheated—room (75 degrees) produces important effects upon the vaso-motor system of the body, including an increase in body temperature and heart rate and a lowering in the Crampton index and in other indices used to indicate a lessened facility of adaptive reaction on the part of the vascular system. These changes were accompanied by marked discomfort and a decrease in the amount of physical work performed. Still more recent experiments, carried out under the direction of Dr. James Alexander Miller of the Commission, have confirmed and extended the investigations of Leonard Hill on the effect of overheated air in promoting congestion of the membranes of the nose, which is believed to be an important factor in promoting bacterial infections of the respiratory tract.

On the other hand, air containing an excess of carbon dioxide as well as all the other chemical constituents imparted to the air of a closed space as a result of human occupancy had no effect on any of the physiological or psychological criteria mentioned above. It did not diminish efficiency and it caused no discomfort.

Relation Between Climate and Efficiency

An interesting series of observations was reported by Prof. Ellsworth Huntington of Yale in the January number of *Harper's Magazine*, which throws a great deal of light upon these problems. Prof. Huntington obtained records of the weekly wages paid out for piece work in three factories in Connecticut for a period of four years and the daily or weekly marks of sixteen hundred students at West Point and Annapolis for periods of two and six years respectively. Curves plotted from these data showed three very striking things. First of all, both physical and mental accomplishment regularly begin to fall off when the outdoor temperature exceeds 65 to 70 degrees. Secondly, there is an even greater decrease in efficiency when the temperature falls below 40 to 50 degrees. Thirdly, changes in temperature in either direction seem to exert a distinctly stimulating effect. These results, so far as they are comparable, are in striking

A SCENE IN THE VENTILATION COMMISSION'S OBSERVATION ROOM.
Studying the Pulse and Blood Pressure, with a Typewriting Operation Test Under Way.

accord with those obtained by physiological research and re-enforce the conclusion that temperature exerts a profound effect upon physical well-being and efficiency.

Practical Conclusions as to Ventilation Needs.

It would be most unfortunate if these conclusions, as to the part played by overheating in producing the evil effects experienced in crowded rooms, should be misinterpreted as meaning that ventilation is a needless luxury. When the progress report of the New York State Commission was discussed in a New York paper under the headline, "Commission Puts its O. K. on Stagnant Air," the Curator of a large college building at once called upon the Chief of our Investigating Staff to ask if he would be justified in stopping his fans. Such a conclusion as this is of course quite unjustified. No scientific investigations can contradict or minimize the well established results of experience as to the bad effects of poor ventilation and the beneficial results of fresh air. What physiological research has done is to show that the commonly observed effects of bad air are due primarily to its high temperature and the lack of cooling air movement, sometimes combined with high humidity. In our experimental rooms we can separate the factors of stagnation and overheating, but in practice an unventilated room (if at all crowded) is an overheated room. Ventilation is just as essential to remove the heat produced by human bodies as it was once thought to be to remove the carbon dioxide produced by human lungs.

Even the quantitative standards of air change, established on the old chemical basis, serve very well on the new physical one. For example, according to von Pettenkofer's classical figure, which is a very low one, an adult gives off 400 British thermal units per hour. Let us assume that this heat must be removed by air entering the room at 60 degrees and leaving it not above 70 degrees. One B. T. U. raises the temperature of about 50 cubic feet of air by 1 degree, or the temperature of 5.0 cubic feet of air from 60 degrees to 70 degrees. Hence our average adult producing 400 B. T. U. will require 2.000 cubic feet of air per hour at 60 degrees to keep the surrounding temperature from rising above 70 degrees. An ordinary gas burner produces 300 B. T. U. per candle power hour; therefore each such burner requires 1,500 cubic feet of air per candle power. These calculations of course ignore direct heat loss through walls and ceiling which, with a zero temperature outside, may carry off the heat produced by 50 or 100 people. Ventilation provisions must, however, be based on the least, rather than on the most favorable conditions. In crowded auditoria every bit of the 2.000 cubic feet of air is needed, and in many industrial processes where the heat produced by human beings and illuminants is reinforced by the friction of machinery and the heat from solder pots, furnaces, mangles, pressing irons, and a host of other sources, even more will be required.

Effect of Chemical Constituents of Air on Appetite

Furthermore, the investigations of the New York State Commission on Ventilation have, during the past year, at last furnished a strong indication that even the chemical constituents of the air of occupied rooms are not without their effect on the human organism. Up to 1914 it had been clearly shown that the ordinary obvious effects experienced in ill-ventilated rooms were due to temperature and humidity and lack of air movement alone, and there was no valid experimental evidence that the chemical changes in such rooms had any physiological effects at all. During the past ten months, however, we have apparently succeeded in demonstrating that such an effect exists, and by a very curious and roundabout method—by the study of the appetite of the subjects under observation.

We have now completed five different experiments, in each of which from four to eight subjects were exposed daily to controlled atmospheric conditions in our experimental room and there served with a standard luncheon of known calorific value. The subjects were allowed to eat as much as they wished and the food uneaten was weighed, so that the amount consumed could be determined. On half the days each group was supplied with fresh air at the rate of 45 cubic feet per minute per capita, and on the other half the air in the room was unchanged, so that the carbon dioxide rose to over 30 parts per 10,000 while all the other chemical substances present in the air of occupied rooms accumulated *pari passu*. Temperature, humidity, and all physical conditions were kept the same on ventilation and no-ventilation days.

In one of the five series of experiments the amount of food eaten was practically the same whether the room was ventilated or not; but this series was conducted under conditions which were not favorable to trustworthy results, since in the middle of the series it was found that religious prejudices were complicating the choice of diet. In all the other four series, the fresh air days showed an average excess in calories consumed ranging from 4.5 to 13 per cent. and averaging 8.2 per cent.

It seems reasonable to suppose that this effect may have been due to a reflex effect of substances in the air, not consciously perceived, for the votes of the subjects as to comfort indicated no preference for the fresh air over the stale air days. In any case, however, the fact is an exceedingly important one. Even a slight restrictive influence upon the appetite would exert profound effects in time; and the beneficial effects of fresh air treatment in tuberculosis and other diseases may be related to this newly demonstrated effect of the chemical constituents of the air of occupied rooms.

The Present Status of Fresh Air

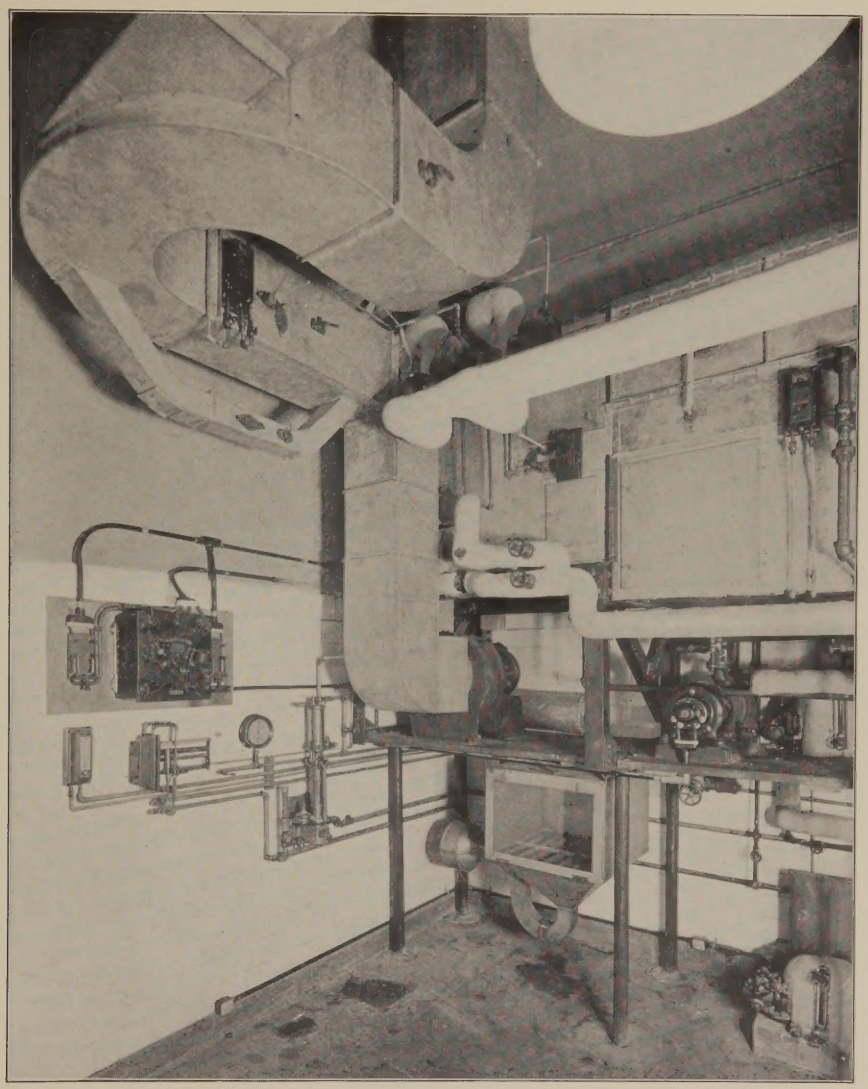
The beneficial effects of open air treatment have of course been clearly demonstrated by innumerable clinical observations and by the

experience of open air schools and day camps without number. In all such cases, however, the subjects have not only been given fresh air to breathe, but cool air, to bathe their faces, and to cool their bodies, more or less effectively, in spite of special clothing.

The results of recent research seem to indicate that an important factor in fresh air treatment is the surrounding of the body and the bathing of the face and the membranes of the nose with cool moving air. Overheating has been shown to produce serious derangements of the vaso-motor mechanism, and a decrease in efficiency and to conduce to an undesirable congestion of the mucous membranes of the nose.

Furthermore, the work of the past year has furnished a strong indication that some of the chemical constituents of stale air exert a subtle harmful effect which manifests itself in a decreased appetite for food.

These investigations confirm and explain the observed results of fresh air treatment and particularly emphasize the importance of temperature as one of the most significant factors in its success. As such researches proceed we may hope to disentangle more and more completely the various influences at work in the outdoor air, to measure their relative importance and to control intelligently, and not empirically, their therapeutic and prophylactic use.



ONE END OF THE APPARATUS ROOM, SHOWING SOME OF THE DEVICES USED TO REGULATE VENTILATION.